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Evaluating tourist importance-performance and support for development in Komodo National Park

Ari Rahman [a], Evi Siti Sofiyah [a,*], Imelda Masni Juniaty Sianipar [b], Amalia Edwisafira [a], Sapta Suhardono [c,*], Chun-Hung Lee [d], Van Viet Nguyen [e], I Wayan Koko Suryawan [a,d,*]

[a] Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Jalan Sinabung II, Terusan Simprug, Jakarta, 12220, Indonesia
[b] Department of International Relations, Faculty of Social Science and Political Science, Universitas Kristen Indonesia, Jakarta, 13630, Indonesia
[c] Environmental Sciences Study Program, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[d] Department of Natural Resources and Environmental Studies, College of Environmental Studies and Oceanography, National Dong Hwa University, Hualien 97401, Taiwan
[e] Faculty of Silviculture, Dong Nai Campus, Vietnam National University of Forestry, Bien Hoa 810000, Dong Nai, Vietnam

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ABSTRACT

This study investigates tourist support for the proposed Jurassic Park development in Komodo National Park, focusing on how various factors such as environmental beliefs, sustainable practices, and visitor experiences influence their perspectives. Using a structured survey administered to 600 domestic and international tourists, this research employs Importance-Performance Analysis (IPA) to identify discrepancies between tourist expectations and perceptions of current park management. Further, Probit and Logit regression models analyze the determinants influencing tourists' support for the development. The findings reveal significant concerns about carrying capacity and environmental impacts, with a strong preference for sustainable development practices among visitors. The study highlights the need for park management to align development strategies with environmental conservation and visitor satisfaction to foster support for future projects. Recommendations include implementing controlled access systems, enhancing visitor education programs, and improving infrastructure with sustainable practices.

1. Introduction

Komodo National Park, a UNESCO World Heritage site located in Indonesia, is renowned globally for its unique biodiversity, including the famous Komodo dragons. The park attracts tourists worldwide, drawn by its natural beauty and the allure of its rare wildlife. However, the increasing interest in developing tourist facilities within the park, including the proposed Jurassic Park development (Choirisa et al., 2021; Zuhri et al. 2021; Hasanah and Bayo 2024; Meckelburg and Wardana 2024), has sparked a complex debate about the balance between tourism growth and environmental conservation. Tourism, if not managed sustainably, can lead to environmental degradation that could threaten the very attributes that make such natural sites appealing (Ghazvini et al. 2020; Lukoseviciute and Panagopoulos 2021; Mandić and Petrić 2021; Ocelli Pinheiro et al. 2021). This tension between development and conservation is a critical issue facing many of the world's protected areas. Komodo National Park's ecosystem is fragile, with its unique flora and fauna highly sensitive to changes in their environment. The Komodo dragons, the park's flagship species, are particularly vulnerable to disturbances due to human activity (Ariefiandy et al. 2021). The park also encompasses significant marine biodiversity, including coral reefs that are susceptible to damage from increased boat traffic and human interaction (Sosnowski et al. 2020; Germanov et al. 2022). These environmental considerations are crucial when planning any development (Bibri et al. 2020), as the impact can extend far beyond the immediate construction area, affecting water quality, natural habitats, and the broader ecological balance.

The proposition of the Jurassic Park development within Komodo National Park has brought critical conservation and governance issues to the forefront. Designed to enhance tourist experiences and attract higher visitor numbers, the project is expected to generate economic benefits at both local and national levels (Tranter et al. 2022). However, it also

* Corresponding authors.
E-mail addresses: es.sofiyah@universitaspertamina.ac.id (E.S. Sofiyah), sapta.suhardono@staff.uns.ac.id (S. Suhardono), i.suryawan@universitaspertamina.ac.id (I.W.K. Suryawan).

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raises serious concerns about the park's infrastructural capacity and the ecological risks associated with increased tourism pressure (Smith et al. 2021). Given the park's fragile ecosystems and the endemic Komodo dragon habitat, any proposed development must undergo a thorough environmental assessment to ensure its compatibility with conservation objectives. Recent literature highlights the project's complexity and controversy, particularly on Rinca Island. Although it is promoted as a Public-Private Partnership (PPP) intended to modernize facilities and improve accessibility (Firmansyah and Putri 2022), the project remains vague in terms of spatial scale, technical design, and the implementation of environmental safeguards. The 2000–2025 Komodo National Park Master Plan mentions zoning and conservation strategies, but offers limited transparency on how these will be enforced in practice. Public communication has also been inconsistent; Sani and Budi (2024) reveal that unclear messaging has fueled polarized sentiment online, contributing to confusion and distrust among stakeholders (Sani and Budi 2022). Critics argue that the project represents a form of hyperreality an artificial vision of conservation commodified for tourism (Gasa et al. 2023), rather than a plan grounded in ecological realities. This critique is echoed by Nusaibah et al. (2022), who interpret the development through the lens of eco-capitalism, viewing it as a neoliberal project that prioritizes economic gain over environmental and community well-being (Nusaibah and Sajidah). Furthermore, concerns about regulatory oversight have been raised. Rusdiana et al. (2022) identify possible violations of Indonesia's environmental impact assessment regulations, suggesting that the project may lack sufficient legal compliance for development within a protected area (Rusdiana et al. 2021). Together, these findings point to a lack of clarity and public accountability in the planning process conditions that complicate how both the public and survey respondents assess the legitimacy and desirability of the Jurassic Park initiative.

Despite the growing recognition of the importance of sustainable tourism practices (Sharpley 2020; León-Gómez et al. 2021; Scott 2021; Font et al. 2023)There remains a significant gap in empirical research concerning the impact of large-scale development projects within such sensitive environments, particularly in protected areas like Komodo National Park. The introduction of the Jurassic Park development presents a unique case to explore these dynamics further (Asriyani and Verheijen 2020; Reindrawati et al. 2022; Gasa et al. 2023), yet few studies have methodically assessed how such projects influence the ecosystem and tourist perceptions in a real-world setting. This development scenario draws upon the exotic appeal of KNP's "erstwhile" nature, notably the presence of the endemic Komodo dragon, across the park's iconic islands 33,987 hectares of Komodo, 19,625 hectares of Rinca, and 1533 hectares of Padar rich in biodiversity and natural resources. Since the inception of KNP's 2000–2025 masterplan, the implementation of zoning regulations has aimed to balance conservation with tourism, although it has also restricted certain traditional livelihoods such as seaweed harvesting and aquaculture (Komar 2024). In this context, the present study aligns closely with the ongoing Jurassic Park development by offering empirical insights into tourist perceptions, environmental concerns, and the level of support for sustainable practices key factors for informing adaptive management strategies as the project advances. While formal mechanisms for incorporating these findings into policy and planning remain undeveloped, the evidence generated provides critical guidance for policymakers, developers, and park authorities in managing the delicate equilibrium between tourism growth and conservation imperatives. By emphasizing visitor expectations alongside environmental priorities, this research delivers actionable recommendations to support decision-making throughout the remaining phases of the Jurassic Park initiative, promoting alignment with sustainable tourism principles and long-term conservation objectives.

Additionally, there is an underexplored area in the literature regarding the perceptions of tourists themselves and how their attitudes towards environmental conservation impact their support for development initiatives within protected areas. Most existing studies focus on general visitor satisfaction or the economic impacts of tourism without a deep dive into how environmental beliefs and the perceived performance of conservation efforts influence visitor support for new developments (Uslu et al. 2020; Sæþórsdóttir and Hall 2020; Biswas et al. 2021; Yu et al. 2021; Torabi et al. 2022; Damanik and Yusuf 2022). Furthermore, while the Importance-Performance Analysis (IPA) tool is frequently used in service industries to assess business performance against customer expectations (Esmailpour et al. 2020; Aghajanzadeh et al. 2022; Aicher et al. 2023), its application in measuring tourist perceptions of the management of natural parks, especially in the context of a new development project, is not extensively explored. For instance, IPA has been used for human–elephant conflict management surrounding a national park in Vietnam (Nguyen et al. 2021), human-wildlife conflict strategies in Chitwan National Park, Nepal (Ferdin et al. 2024). Competitive importance-performance analysis of an Australian wildlife park (Taplin 2012). It has also been applied to guide visitor management at marine wildlife tourism destinations such as the Dolphin Discovery Centre in Bunbury, Western Australia (Simpson et al. 2020), assess mangrove ecotourism in Taman Nasional Bali Barat, Indonesia (Suryawan et al. 2024a), and evaluate visitor satisfaction in the protected areas of the Indian Himalayan Region (Bhalla and Bhattacharya 2021).This study seeks to address these gaps by offering a comprehensive analysis of tourist support for the proposed Jurassic Park development in Komodo National Park. It examines the interaction between tourist expectations, demographic factors, and overall experiences, all within the framework of sustainable tourism. By integrating the IPA approach into a protected area management context, the study contributes new insights into how conservation performance and service quality affect public support for development. The findings are expected to inform park managers and policymakers through evidence-based recommendations that promote environmentally responsible tourism while enhancing visitor satisfaction.

2. Method

2.1. Study location and sample

The study was conducted in Labuan Bajo, the primary gateway for tourists visiting Komodo National Park. A total of 600 tourists, comprising both individuals who had already visited the park and those planning to visit, were randomly selected to participate in the survey. To ensure that the sample was statistically representative of the total tourist population, the required sample size was calculated using Cochran's (1977) formula (Cochran 1977). This method allows for a 95 % confidence level and a margin of error of ±4 %, which are standard thresholds in social science research for achieving generalizability. The annual visitor statistics provided by Komodo National Park were used as the population baseline for the calculation. The formula applied is shown in Eq. (1), where z represents the z-score (1.96 for 95 % confidence), p is the estimated proportion of an attribute (assumed at 0.5 to maximize variability), and e is the desired level of precision (0.04).

$$n = \frac{Z^2\ x\ p\ x\ (1-p)}{e^2} = \frac{1.96^2\ x\ 0.5\ x\ (1-0.5)}{(0.04)^2} == 600.25$$
$$\approx 600 \text{ respondents} \quad (1)$$

This calculation confirms that the sample size used in the study is sufficient to reflect the views of the broader tourist population with a high level of confidence. The inclusion of tourists who planned to visit the park was a deliberate methodological decision. Although these respondents had not yet experienced the park firsthand, they had been extensively exposed to information regarding Komodo National Park and the proposed Jurassic Park development through tour operators, promotional materials, social media, and pre-visit briefings by local guides. These sources significantly shape tourists' expectations and

attitudes prior to their actual visit. Understanding these pre-visit perceptions is critical, as they influence destination image, decision-making, and willingness to support tourism development initiatives. Tourists often form opinions about conservation practices and infrastructure projects based on communicated narratives rather than direct experience.

A comparative analysis was conducted to ensure analytical rigor between respondents who had visited the park and those planning to visit. This allowed for identifying perceptual differences between experiential knowledge and expectation-based assessments. By addressing these distinctions, the study provides a nuanced understanding of how actual experiences and pre-visit information influence tourist attitudes toward environmental conservation and large-scale development within protected areas. The survey instrument was carefully designed to capture these dynamics. Specifically, the questionnaire gathered detailed data on tourists' perceptions and attitudes toward environmental conservation, sustainable tourism practices, and the anticipated impact and management of the Jurassic Park development within Komodo National Park. This approach ensured that both past visitors' experiential insights and prospective visitors' expectations were systematically documented. By integrating these perspectives, the study offers comprehensive evidence to inform adaptive management strategies, enhance communication efforts, and guide policy decisions to balance tourism development with conservation objectives in Komodo National Park.

Fig. 1

2.2. Survey design

From this population, a sample size of 600 respondents was determined using Cochran's (1977) formula, providing statistical significance with a 4 % margin of error at a 95 % confidence level. This sample size was designed to support robust analysis across a wide range of demographic and psychographic characteristics, allowing the findings to be generalized to the overall tourist population of Komodo National Park. To ensure randomness and reduce selection bias, tourists were systematically approached at various entry and exit points in Labuan Bajo, where visitor traffic remained consistent throughout the day. This approach prevented the overrepresentation of any particular time period, visitor profile, or tour group. Participants were selected through a systematic random sampling method, inviting every nth visitor to participate in the survey, ensuring equal inclusion opportunities. This sampling strategy preserved the representativeness of the data, capturing the diversity of tourist experiences and perspectives within the park. The overall study design, encompassing the sampling methodology and data collection process, was carefully structured to uphold rigorous academic standards, ensuring reliability and validity. These methodological considerations contributed to a comprehensive, unbiased, and ethically sound research process, reinforcing the credibility of the analysis and conclusions drawn from the data.

To facilitate effective communication and ensure the comfort and understanding of all participants, the interviewers employed were bilingual, proficient in both Bahasa Indonesia and English. This linguistic capability was essential, especially given the park's international visitor base. Interviews were conducted in Bahasa Indonesia for local visitors and in English for international visitors, thereby accommodating the linguistic preferences of all participants and ensuring that the nuances of their responses were accurately captured without language barriers. Concerning ethical considerations, the study was conducted with strict adherence to ethical norms commonly upheld in social

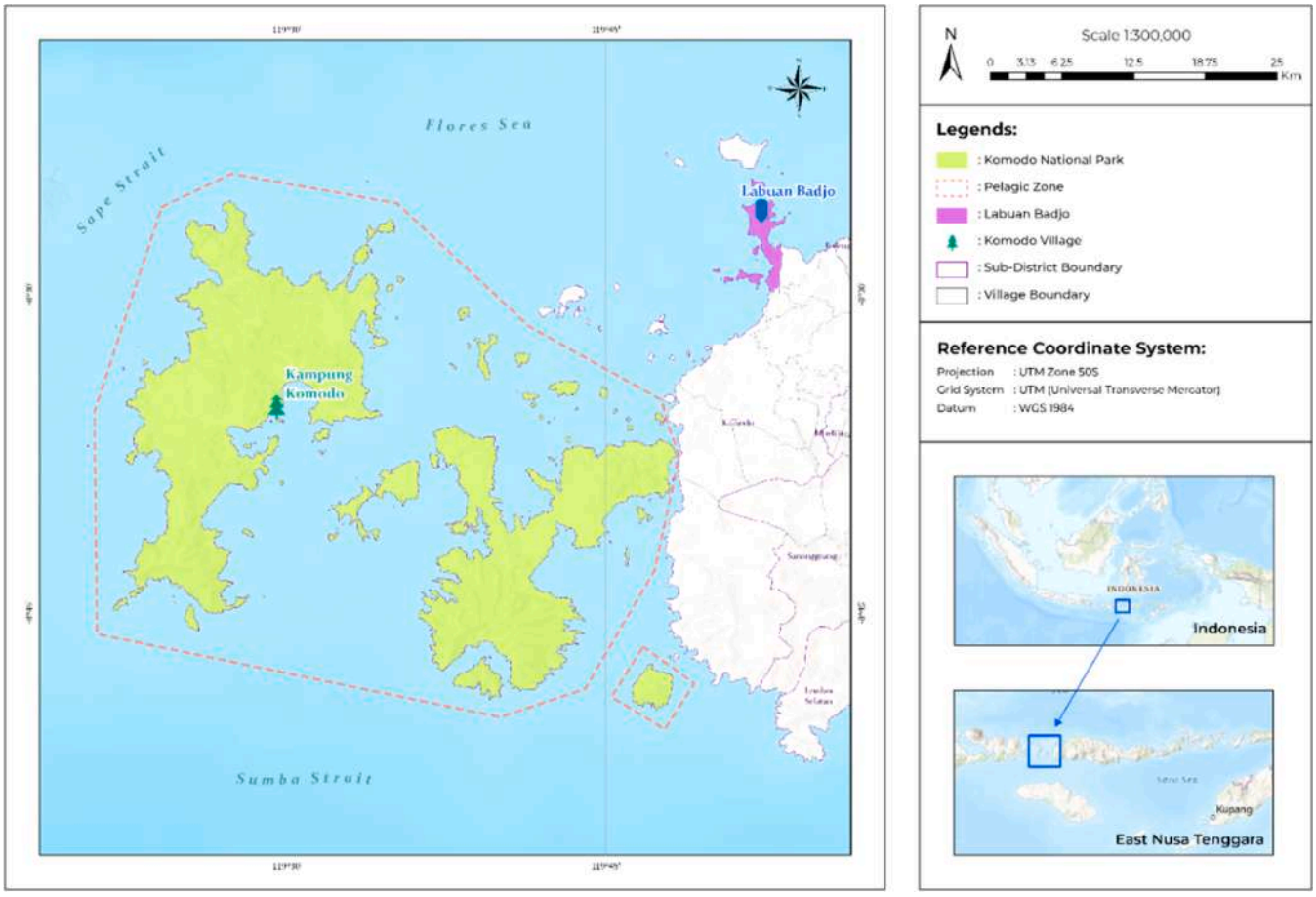


Fig. 1. Geographic context of Labuan Bajo: The gateway to Komodo National Park (Suryawan et al. 2024b).

research. Prior to conducting the survey, the research protocol, including the sampling method and data collection approach, was reviewed and approved by an ethics committee to ensure compliance with both local and international ethical standards. This approval was crucial to address any potential ethical concerns related to privacy, consent, and the use of the data collected.

Informed consent was a cornerstone of the survey execution. Before participation, each respondent was informed about the study's aims, the nature of their involvement, and their rights as participants. This included their right to withdraw from the study at any time without any consequences. Confidentiality and anonymity were rigorously maintained throughout the process. Respondents were assured that all data collected would be anonymized before analysis, and results would be reported in aggregate form only, ensuring that individual responses could not be traced back to them. The administration of the survey was conducted in a manner that respected the time and privacy of the participants. Survey administrators were trained not only in the technical aspects of administering the questionnaire but also in ethical communication to ensure that interactions with participants were conducted respectfully and professionally.

2.3. Data collection

The survey instrument designed for this research was meticulously crafted to collect comprehensive data on the complex interplay of tourism impacts at Komodo National Park, aiming to gather deep insights into visitors' perceptions and behaviors related to sustainable tourism and development initiatives within this ecologically sensitive area. Part 1 of the questionnaire was dedicated to understanding tourists' environmental beliefs and attitudes. This segment sought to assess the level of environmental consciousness among respondents and their attitudes toward sustainable tourism practices. Questions were formulated to explore tourists' self-perceived roles and the impacts of their activities on the environment, which is vital for gauging their support for conservation-oriented initiatives within the park.

Part 2 of the questionnaire was specifically designed to explore tourists' views on the proposed Jurassic Park development in Komodo National Park. This part examined the perceived impacts of this development on the local ecosystem and community. It incorporated items based on the Importance-Performance Analysis (IPA) model, targeting various aspects of park management and infrastructure critical for ecological sustainability and visitor satisfaction. Respondents rated each item using a Likert scale from 1 (very unimportant/strongly dissatisfied) to 5 (very important/strongly satisfied), which helped identify critical gaps where visitor expectations did not align with their actual experiences. This evaluation was crucial for pinpointing areas needing attention and resource allocation, informed by the International Union for Conservation of Nature (IUCN) standards for managing environmental impacts.

Part 3 of the questionnaire gathered demographic data such as age, gender, income, educational level, and nationality to provide context for analyzing how different tourist groups perceive environmental and development issues. This structured approach ensured that the findings could effectively guide strategies for improving visitor experience while maintaining ecological integrity. To refine the questionnaire, a pretest was conducted with 58 visitors in November 2023, followed by a pilot test during December 2023 to January 2024, which coincides with the peak tourism season in Komodo National Park. This timing ensured the study captured attitudes from a broad and active visitor base, reflecting typical peak-season tourist experiences. The primary survey was carried out during this same period. We acknowledge that perceptions may vary between seasons and recommend future research to include off-peak comparisons for a fuller understanding.

2.4. Data analysis

This study employed a multi-stage analytical framework to explore tourist perceptions and support for the proposed Jurassic Park development in Komodo National Park. The objective was to identify service gaps, understand variations in attitudes across visitor groups, and determine the key drivers influencing support for the development. The analysis began with a paired sample *t*-test to compare tourists' importance ratings and perceived performance for various park attributes. This statistical test assessed whether there were significant differences between what visitors value and how well they believe those attributes are managed. It helped identify service areas where performance fell short of expectations particularly in environmental sustainability, waste management, and infrastructure quality highlighting opportunities for targeted improvement. A segmentation analysis was conducted using cluster techniques to understand further how different types of tourists perceive the park and its development. This classified the 600 respondents into relatively homogeneous groups based on their sociodemographic characteristics such as age, nationality, income level, education, and environmental attitudes. Segment-level insights enabled the research to offer more tailored recommendations for communication and policy strategies, ensuring that diverse visitor concerns could be more effectively addressed.

A central part of the analysis involved the application of Importance-Performance Analysis (IPA). This approach plotted tourists' ratings of each attribute's importance against their perceived performance. The resulting grid provided a visual overview of how well the park's services and development plans aligned with tourist expectations. Attributes rated as high in both importance and performance indicated areas of sustained success. Attributes with high importance but low performance signaled priority areas where immediate management intervention was needed. Meanwhile, attributes with high performance but low importance were identified as possible areas of over-investment, and those with low scores on both dimensions were seen as lower priority for immediate resource allocation. This IPA framework allowed park managers to see where strategic focus should be directed clearly (Imelda et al. 2024; Suryawan et al. 2024a). The four quadrants of the grid provided a strategic view:

- Sustained Success Sector (High Importance, High Performance): Attributes in this quadrant are well-managed and crucial to tourists, suggesting that current efforts should be maintained to continue meeting visitor expectations.
- Priority Action Zone (High Importance, Low Performance): This quadrant highlighted critical areas where tourists felt that performance did not meet their high expectations. Focus on these areas could significantly improve overall satisfaction and perception of the park.
- Marginal Gains Area (Low Importance, High Performance): Attributes in this quadrant were performing well, though they were not deemed very important by tourists. This suggests that resources currently dedicated here could be reallocated with minimal impact on overall visitor satisfaction.
- Resource Reallocation Region (Low Importance, Low Performance): The low ranking on both axes suggested that these attributes, while underperforming, were not critical to tourist satisfaction and thus, could be lower priorities in terms of immediate resource allocation.

Fig. 2

To deepen the analysis beyond descriptive statistics and IPA results, this study employed Logit and Probit regression models to quantitatively examine the determinants of tourist support for the Jurassic Park development in Komodo National Park. These models were chosen for their suitability in estimating binary response outcomes, whether a tourist supports the proposed development (1 = support, 0 = not support). The regression analysis was based on a set of independent

Fig. 2. Importance-Performance Analysis (IPA) grid for tourist ratings of attributes (Martilla and James 1977).

variables identified as significant during the segmentation and IPA analyses. These included attitudinal variables such as agreement to control carrying capacity, belief in environmental impact, and preference for environmentally friendly practices (all coded as 1 = yes, 0 = otherwise). Behavioral and demographic variables were also incorporated, including visitation history (1 = has visited Komodo at least once), origin (1 = Indonesian, 0 = international), and education level (1 = bachelor's degree or higher). Crucially, the models also integrated two continuous variables: the average perspective of importance (reflecting the mean importance score tourists assigned to park attributes) and the average value of service performance (capturing the perceived performance of those same attributes). These variables represent the core of the IPA framework and were included in the regression to assess how perceived importance and satisfaction interact in shaping tourists' willingness to support development. By combining these data sources, the Probit and Logit models provided robust estimates of the probability of support based on a mix of perception-driven and socio-demographic factors. The results revealed that tourists with higher environmental concerns were significantly less likely to support the development unless sustainable safeguards were communicated. Meanwhile, repeat visitors and those with higher education showed differentiated support patterns, suggesting stronger emotional and cognitive ties to the park and its long-term ecological health. These findings reinforce the IPA conclusions by showing that not only do tourists place high importance on sustainability and environmental performance, but that these perceptions directly influence their behavioral intentions. Including importance and performance scores in the regression provides a unique empirical contribution, linking managerial perceptions with predictive behavioral modeling.

2.5. Respondents characteristics

Demographic and attitudinal data were systematically collected through a structured questionnaire to ensure the sample reflected a diverse cross-section of tourists including variations in age, income level, educational background, nationality, and visitation experience. Table 1 summarizes the characteristics of all 600 respondents included in the main survey. The gender distribution was nearly even, with 46.83 % female and 53.17 % male participants, while 41.17 % were international tourists, ensuring that both domestic and global

Table 1
Characteristics of Respondents in the Main Survey ($N = 600$).

Variable	Category	n	%
Gender	Female	281	46.83 %
	Male	319	53.17 %
Origin	Domestic (Indonesian)	353	58.83 %
	International	247	41.17 %
Education Level	≥ Diploma/bachelor's degree	261	43.50 %
	< Diploma	339	56.50 %
Monthly Income	> IDR 3000,000	273	45.50 %
	≤ IDR 3000,000	327	54.50 %
Visitation History	Has visited before	92	15.33 %
	First-time visitor	508	84.67 %
Agreement to control carrying capacity	Agree	141	23.50 %
	Disagree	459	76.50 %
Belief in environmental impact	Yes	183	30.50 %
	No	417	69.50 %
Prefer environmentally friendly practices	Yes	278	46.33 %
	No	322	53.67 %

perspectives were incorporated. In terms of educational attainment, 65.5 % of respondents had completed a diploma or bachelor's degree or higher, indicating a generally high level of formal education among participants. This was complemented by economic diversity: 45.5 % of respondents reported a monthly income above IDR 3000,000, while 54.5 % fell below this threshold, capturing a range of socioeconomic backgrounds relevant to understanding willingness to support conservation-related tourism initiatives. Tourist behavior and experience were also well represented. A majority of respondents (84.67 %) were first-time visitors to Komodo National Park, while 15.33 % had visited before. This balance allowed the study to assess both expectation-based perceptions and experience-informed evaluations. In addition to sociodemographic variables, the study captured critical attitudinal indicators related to environmental awareness and sustainability values. For example, 46.33 % of respondents indicated a preference for environmentally friendly practices, and 30.50 % acknowledged the environmental risks posed by tourism development. Furthermore, 23.50 % supported carrying capacity controls as a means of protecting the park's ecological integrity.

The inclusion of these diverse variables supports the study's internal validity and reinforces the analytical robustness of segmentation and regression analyses. The random sampling strategy successfully yielded a broad mix of age groups, economic classes, educational levels, and environmental attitudes, offering a rich dataset for subgroup comparisons and behavioral modeling. These characteristics confirm that the sample is both statistically representative and substantively diverse, thereby providing a solid foundation for deriving generalizable insights into tourist support for sustainable development in Komodo National Park.

3. Result

Table 2 presents a detailed paired sample *t*-test analysis to examine the disparities between perceived importance and performance of various environmental and infrastructure indicators within a protected area. In analyzing environmental and infrastructure services within a protected area, stakeholders have rated various indicators in terms of their importance and the actual performance experienced. The indicators cover a broad spectrum, ranging from the management of transportation to the preservation of natural habitats and the mitigation of noise pollution. This comprehensive evaluation helps identify critical gaps that could inform targeted improvements and strategic planning. Public transportation services, essential for visitor access and mobility within the park, have been highlighted as needing significant improvement, reflecting a gap between the current service levels and

Table 2
Paired sample *t*-test results for importance and performance of each indicator.

No	Indicators	Importance		Performance		GAP (Importance and Performance)		t	Sig. (2-tailed)
		Mean (Stdev)	Rank	Mean (Stdev)	Rank	Gap	Rank		
1	Public transportation	4.090 (1.091)	12	3.025 (1.083)	12	1.065	3	18.856	< 0.01
2	Habitat of Komodo dragons	4.628 (0.731)	1	3.687 (1.146)	3	0.942	9	19.799	< 0.01
3	Green infrastructure	4.442 (0.756)	8	3.718 (1.046)	2	0.723	14	15.467	< 0.01
4	Coral reefs	4.507 (0.764)	4	3.768 (1.112)	1	0.738	13	16.015	< 0.01
5	Transportation noise	3.797 (1.280)	13	2.797 (1.161)	14	1.000	5	17.913	< 0.01
6	Construction noise	3.715 (1.301)	14	2.792 (1.132)	15	0.923	10	16.686	< 0.01
7	Lighting	4.405 (0.805)	9	3.528 (1.101)	6	0.877	11	18.167	< 0.01
8	Vandalism	3.693 (1.325)	15	2.973 (1.128)	13	0.720	15	13.327	< 0.01
9	Hazard signs for natural events	4.500 (0.796)	5	3.683 (1.160)	4	0.817	12	16.814	< 0.01
10	Residential area orderliness	4.337 (0.857)	11	3.288 (1.088)	10	1.048	4	20.331	< 0.01
11	Marine debris	4.368 (1.045)	10	3.243 (1.296)	11	1.125	2	20.507	< 0.01
12	Waste disposal facilities	4.597 (0.767)	2	3.382 (1.230)	9	1.215	1	21.929	< 0.01
13	Pedestrian facilities	4.468 (0.779)	7	3.497 (1.160)	8	0.972	7	19.158	< 0.01
14	Marine protection explanation	4.483 (0.807)	6	3.500 (1.154)	7	0.983	6	19.374	< 0.01
15	Management of Komodo island	4.572 (0.737)	3	3.602 (1.079)	5	0.970	8	20.592	< 0.01

stakeholders' expectations. The management of the habitat of Komodo dragons stands out as a high-priority area, given its top ranking in importance, yet there's a notable performance gap, indicating a need for enhanced conservation efforts.

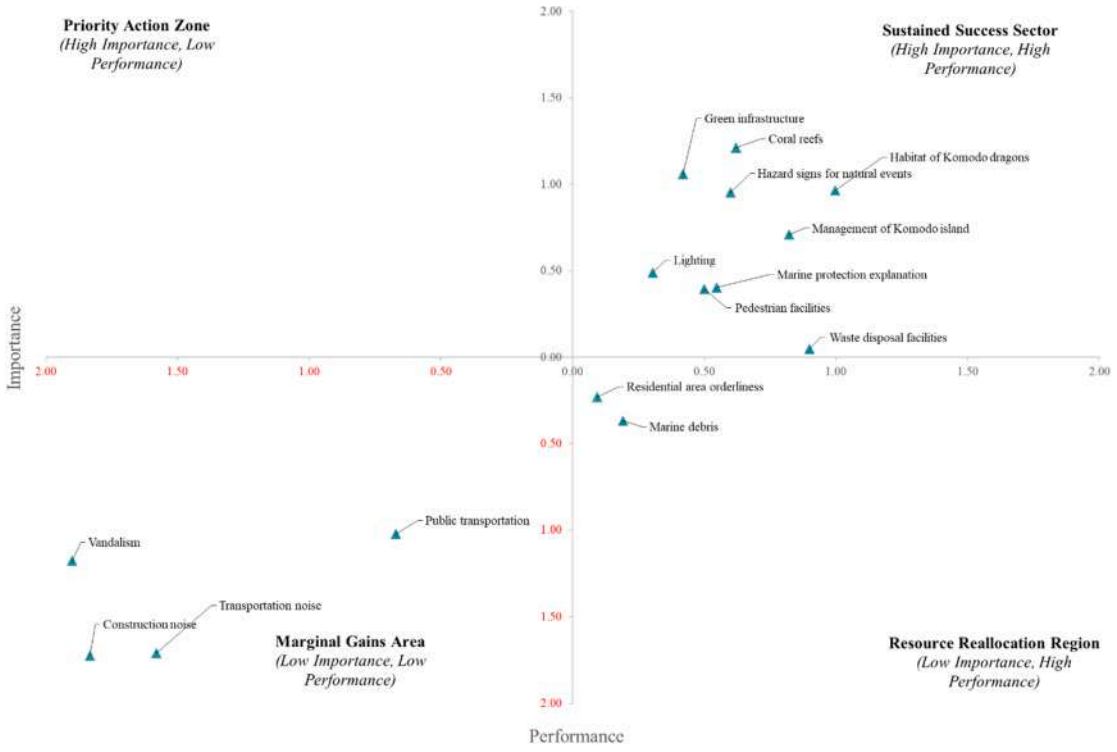
The infrastructure related to green initiatives, such as green infrastructure itself, is deemed crucial by stakeholders but shows discrepancies in execution, suggesting room for development in sustainability practices within the park. Similarly, coral reefs, vital for marine biodiversity, are well-regarded in importance yet face challenges in management effectiveness, pointing to a need for robust marine protection strategies. Noise pollution from transportation and construction is another area where significant gaps have been identified. The noise not only disrupts the visitor experience but potentially threatens wildlife, indicating an urgent need for noise management policies that protect both the natural environment and the quality of visitor engagements. Lighting and safety measures, such as hazard signs for natural events, are also highlighted as areas where performance could be enhanced to match their perceived importance. This is crucial for ensuring visitor safety and maintaining the integrity of the natural environment. Issues like vandalism and managing marine debris are critical, with stakeholders emphasizing the importance of addressing these to prevent damage to natural resources and ensure the sustainability of the park's ecosystems.

Table 3 analyses how various socio-demographic factors and individual attitudes impact tourists' willingness to support the Jurassic Park of Komodo development. Using Pearson's chi-square test, the study identifies significant differences in support levels among distinct respondent groups. One of the standout findings is the concern over the development's environmental management, particularly the agreement to control carrying capacity. Here, 17.33 % of the development's supporters agree on the necessity of controlling carrying capacity, compared to 23.50 % of non-supporters, reflecting a notable divergence in environmental concern ($p < 0.001$). Similarly, the belief in environmental impact showcases a stark contrast between supporters and non-supporters; only 6.83 % of supporters acknowledge potential environmental impacts, compared to 30.50 % among non-supporters ($p < 0.001$). This highlights a significant skepticism among its supporters about the development's environmental claims. Preferences for environmentally friendly practices also show a significant difference; 22.33 % of supporters prefer eco-friendly practices versus 46.33 % of non-supporters ($p = 0.001$), indicating that those who favor environmentally friendly measures are less inclined to support the development. The frequency of visits to the area significantly affects willingness to support the development ($p = 0.001$), with past visitors displaying varied support levels based on their experiences. Demographic factors such as gender and income are also critical, showing a significant correlation with support levels. Females and individuals with higher income levels are more likely to support the development (gender, $p < 0.001$; income, $p < 0.001$). Similarly, educational attainment influences support, with those holding higher educational degrees showing greater likelihood of supporting the project ($p < 0.001$). Interestingly, the origin of the tourists, whether national or international, does not significantly influence support for the development ($p = 0.278$), suggesting that attitudes towards the development transcend geographical boundaries.

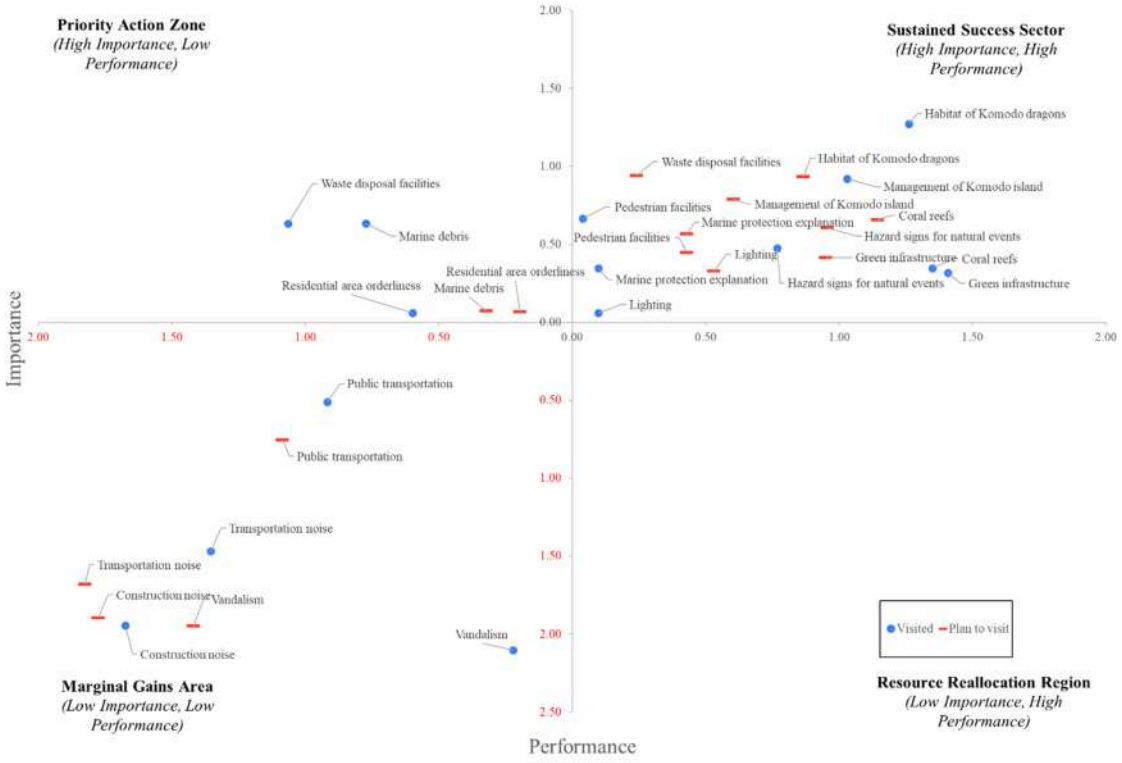
Table 3
Segmentation analysis: tourist attitudes and demographics regarding support for Jurassic Park development in Komodo National Park.

Variables	Willingness to support Jurassic Park of Komodo development				Statistical significance
	Visited respondents		Overall of respondents		
	n	%	n	%	
Agreement to control carrying capacity (1=yes; otherwise=0)	104	17.33 %	141	23.50 %	Person $\chi2$= 40.633; $p < 0.001$
Belief in environmental impact (1=yes; otherwise=0)	41	6.83 %	183	30.50 %	Person $\chi2$=17.708; $p < 0.001$
Prefer for environmentally friendly practices (1=yes; otherwise=0)	134	22.33 %	278	46.33 %	Person $\chi2$= 11.374; $p = 0.001$
Visiting (1 = 1 or more times; otherwise=0)	58	9.67 %	92	15.33 %	Person $\chi2$= 10.517; $p = 0.001$
Gender (1=Female; Male=0)	82	13.67 %	281	46.83 %	Person $\chi2$= 14.931; $p < 0.001$
Origins (1=National Indonesia visitor; otherwise=0)	133	22.17 %	353	58.83 %	Person $\chi2$= 1.178; $p = 0.278$
Income (1=More than IDR 3.000.000/month; otherwise=0)	135	22.50 %	273	45.50 %	Person $\chi2$= 14.196; $p < 0.001$
Education (1=bachelor's/ diploma degree and above; otherwise=0)	132	22.00 %	261	43.50 %	Person $\chi2$= 15.489; $p < 0.001$

Figs. 3a and 3b illustrate the Importance-Performance Analysis (IPA) grids for evaluating environmental impact reduction in Komodo National Park based on tourists' assessments. The grids map the importance and performance of various conservation and service factors, breaking them into four strategic quadrants to guide resource allocation and management focus. In the "Priority Action Zone," which captures factors of high importance but low performance, urgent improvements



3a. Overall of respondents



3b. Comparison of visited and plan to visit for respondents

Fig. 3. IPA grid assessing environmental impact reduction outcomes in Komodo National Park.

are necessary. Here, attributes like waste disposal facilities and marine debris management are positioned, indicating that despite being crucial to tourists and the park's ecological health, they are not meeting expectations. This discrepancy underscores a significant opportunity for intervention to enhance visitor satisfaction and environmental outcomes.

Conversely, the "Sustained Success Sector" features elements such as coral reef preservation and the governance of Komodo Island, which are both well-regarded and well-executed. These are areas where current strategies work effectively, reflecting successful management aligning with tourist expectations and conservation goals. Maintaining these efforts is vital to continuing the park's appeal and ecological stability. The "Marginal Gains Area" includes lower-priority issues like transportation noise, where both the importance and performance are low. Improvements in this quadrant are likely to yield only marginal increases in tourist satisfaction or environmental impact, suggesting that while these areas may benefit from minimal resource investment, they should not detract from focusing on more critical issues. Lastly, the "Resource Reallocation Region" identifies areas such as vandalism and the orderliness of residential areas, which perform well but are not deemed highly important by visitors. This suggests that resources currently used here could be better deployed towards more impactful areas without negatively affecting the overall tourist experience. The comparison between the overall responses and those segmented by visitors' actual experience versus their plans to visit offers deeper insights into how different groups perceive the park's attributes. This nuanced understanding can help park administrators and stakeholders tailor their management practices to address specific needs and expectations, ensuring both the sustainability of the park's natural resources and the satisfaction of its visitors. This strategic approach not only enhances the management of Komodo National Park but also serves as a model for other protected areas facing similar challenges.

Table 4 presents a comprehensive analysis using Probit and Logit models to explore the factors influencing tourist support for the Jurassic Park development in Komodo. The results demonstrate a nuanced relationship between various predictors and the willingness of tourists to endorse the development. The models show that the agreement to control carrying capacity has a consistent negative effect across Probit models ($p < 0.05$), with tourists who agree to such measures less likely to support the development. This trend is also observed in the Logit models, although it does not reach statistical significance, which could suggest a variation in the impact depending on the modelling approach. Belief in the environmental impact of the development, although positive across all models ($p < 0.05$). This finding indicates that tourists who recognize the environmental impacts are more inclined to support the development when more factors are considered in the model. Preferences for environmentally friendly practices show a positive correlation with support in the initial Model I and II ($p < 0.05$), suggesting that tourists favoring sustainability are more supportive of the project. However, this variable does not maintain significance in other models, pointing to potential complexities in how environmental preferences translate into development support.

The variable capturing the frequency of visits to the area shows that more frequent visitors are less likely to support the development, with significant negative coefficients in later models ($p < 0.01$), suggesting that familiarity with the area might increase sensitivity to potential changes due to the development. Tourist origin, identified as whether they are national Indonesian visitors or not, shows a positive correlation with support ($p < 0.01$), but this effect fades in other models. This outcome may reflect the different perspectives between domestic and international tourists on development impacts. Educational level is another significant predictor, with a consistently negative relationship across models ($p < 0.01$), indicating that higher education levels may correlate with more critical views on the development's potential impacts. Furthermore, the average perspectives of importance and performance of service variables introduce significant impacts in their respective models. A higher average perspective of importance leads to increased support in Probit model I ($p < 0.01$), while a better average service performance is significantly related to support in Logit model IV ($p < 0.01$). These results underscore that perceptions of importance and actual service performance are critical in shaping tourist support.

Table 4
Probit and logit models: Analysing tourist support for jurassic park development in komodo including importance and performance interactions.

Variables	Probit		Logit	
	Model I Coef. (S.E)	Model II Coef. (S.E)	Model III Coef. (S.E)	Model IV Coef. (S.E)
Constant	−6.315 (0.666) ***	−5.590 (0.564) ***	−11.220 (1.241) ***	−9.664 (1.026) ***
Agreement to control carrying capacity (1=yes; otherwise=0)	−0.237 (0.116) **	−0.027 (0.120)	−0.411 (0.206) **	−0.095 (0.213)
Belief in environmental impact (1=yes; otherwise=0)	0.374 (0.146) **	0.355 (0.159) **	0.653 (0.265) **	0.579 (0.279) **
Prefer for environmentally friendly practices (1=yes; otherwise=0)	0.239 (0.116) **	0.028 (0.120)	0.414 (0.206) **	0.096 (0.213)
Visiting (1 = 1 or more times; otherwise=0)	−0.391 (0.165) **	0.639 (0.222) ***	−0.729 (0.294) **	1.206 (0.407) ***
Origins (1=National Indonesia visitor; otherwise=0)	0.610 (0.168) ***	0.130 (0.195)	1.107 (0.301) ***	0.173 (0.345)
Education (1=bachelor's degree and above; otherwise=0)	−0.478 (0.160) ***	0.098 (0.165)	−0.872 (0.290) ***	0.172 (0.291)
Average perspective of importance	1.624 (0.152) ***		2.885 (0.288) ***	–
Average value of service performance	–	1.850 (0.164) ***	–	3.214 (0.304) ***
Log likelihood function	−219.843	−179.377	−219.051	−181.196
LLR	275.6032	356.534	277.188	352.8975
McFadden Pseudo R-squared	0.385303	0.498448	0.388	0.493364
AIC/N	0.759	0.625	0.757	0.631
$\chi 2$	df=7(18.475; 0.01)			

Notes: ***, **, * are significant differences at $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

4. Discussion

The Importance-Performance Analysis (IPA) conducted as part of this study provided significant insights into how tourists perceive various aspects of Komodo National Park and the proposed Jurassic Park development. The analysis identifies gaps between the importance tourists place on different park attributes and their perceptions of current performance, pointing out critical areas that require management attention to better meet visitor expectations. Public transportation within Komodo National Park, despite not being viewed as crucial by tourists, underperformed relative to their expectations, placing it in the marginal gain area of the IPA grid. Enhancing public transportation could significantly improve the visitor experience by making park access more convenient and reducing carbon footprint (Gühnemann et al. 2021; Campos et al. 2022; Spernbauer et al. 2022; Zhou et al. 2024). Waste management, including the handling of marine debris which is central to the park's attraction, ranked high in importance but was perceived to be inadequately managed. Tourists have expressed

concerns about waste management and stressed the need for better protection measures to ensure a cleaner habitat for the park's iconic species (Linnes et al. 2022; Panwanitdumrong and Chen 2022). In the realm of green infrastructure, tourists expect sustainable success, emphasizing the need for eco-friendly facilities that integrate seamlessly with the natural landscape without compromising the park's ecological integrity. While these facilities are important, the perceived performance did not fully meet visitor expectations, indicating a pressing need for sustained investment in sustainable infrastructure (Zhuang et al. 2022; Baloch et al. 2023). Coral reefs, essential to the park's marine biodiversity, received high marks for importance and are adequately protected against threats like coral bleaching and human interference. Nevertheless, enhancing coral reef conservation efforts could boost marine biodiversity and increase tourist satisfaction for those coming to experience the park's underwater environments (Piñeiro-Corbeira et al. 2020; Giglio et al. 2022).

Noise from transportation and construction were areas of significant tourism concern (Ștefănică et al. 2021). Both factors were seen as detracting from the natural tranquility of the park, with construction noise identified as particularly disruptive. Addressing these noise concerns would involve better planning and scheduling of construction activities to minimize their impact on visitors and wildlife .Lighting was highlighted as a success in enhancing park services, especially along pathways and communal areas, improving safety and accessibility during evening hours. Optimizing lighting while ensuring it does not interfere with the natural behaviors of nocturnal wildlife could significantly enhance visitor experiences (Falcón et al. 2020; Jägerbrand and Bouroussis 2021), could improve visitor experiences significantly. vandalism and the adequacy of hazard signs for natural events were recognized as areas demonstrating good performance and importance. Implementing effective measures to curb vandalism and enhancing signage could improve safety and help preserve the park's natural heritage (Yates et al. 2022; Yang 2024). The orderliness of residential areas adjacent to tourist facilities and pathways was another point of contention. Visitors felt that these areas could be better maintained to enhance the overall aesthetics and cleanliness of the environment (Zhou et al. 2021; Vaz de Freitas et al. 2022), reflecting the park's commitment to high standards. Marine debris and waste disposal facilities were identified as critical yet underperforming. Tourists were particularly concerned about the effects of waste on marine life and the overall cleanliness of the park. Enhancing waste management facilities and practices is crucial for maintaining the ecological balance and visitor satisfaction (Lukoseviciute and Panagopoulos 2021; Perkumienė et al. 2023).

Additionally, pedestrian infrastructure such as walkways and bridges is recognized as vital for ensuring a safe and enjoyable experience within the park. While these facilities currently meet visitor expectations, there is a noticeable need for ongoing maintenance and strategic upgrades to keep pace with the growing foot traffic and prevent potential safety hazards. Lastly, there is a significant demand for better communication regarding marine protection measures and the overall management of Komodo Island. Tourists are seeking clearer and more accessible information about conservation efforts. Improving how this information is delivered and enhancing management practices could better align visitor perceptions with the realities of conservation efforts in the park (Evans et al. 2021; Xie et al. 2023; Zhang et al. 2023). Providing detailed, transparent explanations about the initiatives undertaken to protect marine life and manage the park's natural resources would likely enhance visitor engagement and support for conservation measures.

The findings from this study on the support for the Jurassic Park development in Komodo National Park provide several actionable insights for policymakers, park management, and developers. These insights point towards the need for carefully balanced strategies that address environmental concerns while developing tourism infrastructure (Mamirkulova et al. 2020; Wardana et al. 2021; Baloch et al. 2023). Firstly, the agreement to control carrying capacity has significant policy and park management implications. The reluctance to support development among those who favor capacity controls suggests a policy opportunity to implement strict visitor management strategies that could mitigate the potential negative impacts of increased tourist traffic. Instituting a cap on daily visitor numbers (Rocha et al. 2021; Xiao et al. 2023), timing entry to the park, and perhaps even a reservation system, could alleviate concerns about over-tourism and its ecological impacts. Such measures would not only preserve the natural habitat but also enhance the visitor experience by preventing overcrowding (Mateos et al. 2020; Xiao et al. 2023)The belief in the development's environmental impact, notably where it increases support for the project, indicates that transparent communication about environmental management strategies and their effectiveness is crucial. Policymakers and developers should focus on detailed environmental impact assessments made public to educate potential tourists about the mitigative steps to minimize ecological disturbances. Moreover, ensuring that these strategies are scientifically sound and vetted by environmental experts can provide additional reassurance to sceptics.

The IPA results further reinforce the critical role of embedding sustainable development practices at the core of the Jurassic Park project. Attributes such as green infrastructure, waste disposal facilities, and marine protection measures were positioned in either the priority action zone or the sustained success sector, indicating that tourists place high importance on environmentally friendly practices but perceive varying levels of performance. The underperformance of waste management and marine debris handling, despite their recognized importance, highlights an urgent need for improved sustainability measures. This supports the argument that adopting green building technologies, enhancing waste minimization strategies, promoting energy efficiency, and implementing sustainable water management systems are not only environmental imperatives but also key to meeting visitor expectations (Chaudhary et al. 2024; Mattiello et al. 2024; Karsokiene et al. 2025). Policies fostering these practices can attract environmentally conscious tourists and establish a benchmark for future eco-sensitive developments in protected areas (Khan and Ramalingam 2023; Mitra and Paul 2025; Singh et al. 2025). However, while these perception-based insights are valuable, they must be interpreted alongside ecological evidence. Scientific studies indicate that Komodo dragon populations are already under pressure from human activities. On Flores Island, for instance, Komodo dragon presence has become restricted to three isolated areas along the northern and western coastlines, with individuals detected at only 85 of 346 monitored locations reflecting a significant reduction in range likely caused by habitat encroachment and disturbance (Ariefiandy et al. 2021). Within the park itself, tourism activity may influence Komodo dragon behavior and population structure, potentially leading to adult-biased populations, altered foraging patterns, and increased intraspecific competition when human-provided food is withdrawn (Ardiantiono et al. 2018). In addition to tourism-related impacts, the threat of climate change poses a serious long-term challenge. Modeling by Jones et al. (2020) predicts that Komodo dragon habitat could decline by 8 %–87 % by 2050, resulting in local extinctions across many island populations and declines in overall abundance ranging from 27 %–99 %. Although Rinca and Komodo Islands may serve as "safe havens" due to their protected status, the scale of habitat loss across the species' range is alarming and reinforces the urgency of integrating climate resilience into development planning (Jones et al. 2020). Efforts to restore degraded areas within the park, such as mined-out forest lands, have shown positive progress. Rehabilitation assessments conducted by Sudarmadji and Hartati (2021) report an average ecological recovery score of 86.0 across several sites. However, the functional recovery of food webs remains limited, with a food web health score of 70 classified as "prospective," indicating ongoing ecological vulnerability due to the absence of top predators (Sudarmadji and Hartati 2021). Moreover, unmanaged tourism activities contribute to litter pollution in both the terrestrial and marine zones of the park. This has been linked to ecosystem degradation, aesthetic loss, and

reduced tourist satisfaction. Recent studies emphasize the importance of improving waste infrastructure and educating visitors to reduce plastic and solid waste pollution in Komodo National Park (Cordova et al. 2021; Suryawan et al. 2024b, 2025c).

The IPA also reveals that visitors who have previously experienced Komodo National Park are more critical of developments that risk altering its natural authenticity. This aligns with findings that emphasize the importance of maintaining a destination's environmental character to sustain tourist satisfaction and loyalty (Kusdibyo 2022; Zulvianti et al. 2023; Kusumah 2024). Ensuring that new infrastructure harmonizes with the existing landscape, rather than dominating it, is essential for preserving the park's identity. Moreover, the variation in perceptions between domestic and international tourists, as reflected in the IPA segmentation, underscores the necessity for tailored communication strategies. Culturally adaptive outreach campaigns can enhance engagement by aligning messaging with specific values and expectations (Urich et al. 2024; Bharti et al. 2025; Suryawan et al. 2025a). According to the analysis, visitors with higher education levels who tend to exhibit more skepticism toward the development of educational initiatives highlighting conservation outcomes funded by tourism revenues could shift perceptions positively. Finally, the IPA's emphasis on attributes clustered around average importance and performance suggests that continuous quality management is vital. Regular facility assessments, infrastructure upgrades, and comprehensive staff training in customer service and environmental education are critical to enhancing tourist satisfaction and fostering long-term support for sustainable development (Achmad et al. 2023; Qamruzzaman 2023; Noor and Sharma 2024; Vardopoulos et al. 2024). This approach aligns with best practices in sustainable tourism management, where ongoing service improvement directly correlates with visitor support for conservation-linked initiatives (López-Mosquera and Sánchez 2011; Batel et al. 2014; Jayaratne et al. 2023; Musa and Nadarajah 2023; Suryawan et al. 2025b).

Based on our findings from the study on tourist support for the Jurassic Park development in Komodo National Park, several key policy recommendations emerge to enhance both conservation efforts and visitor experiences. These policies are designed to align local initiatives with global conservation standards set by the International Union for Conservation of Nature (IUCN). A central finding highlights the urgent need for strict management of visitor numbers, which addresses not only the future challenges of mass tourism and overtourism currently observed in Komodo National Park but also anticipates potential pressures arising from the Jurassic Park initiative. The current tourism dynamics and the planned development underscore the necessity of implementing effective visitor control measures. In this context, the Jurassic Park initiative should be viewed as an opportunity to introduce structured solutions, such as a reservation system, to regulate tourist flows. Such a system could mitigate the negative environmental impacts of overcrowding, safeguard biodiversity, and enhance the overall visitor experience by reducing congestion. This approach directly aligns with IUCN recommendations for managing sensitive ecosystems under tourism pressure. Furthermore, transparency in environmental management remains critical. Mandating publicly accessible environmental impact assessments ensures that stakeholders remain informed about ongoing tourism impacts and those anticipated from future developments. This openness fosters trust and reinforces a commitment to sustainable practices. Integrating sustainable infrastructure, including renewable energy, waste management, and water conservation, is essential to position the Jurassic Park project as a model for responsible tourism. Our study indicates that environmentally conscious tourists are more supportive when such practices are visibly embedded within development strategies. Additionally, targeted educational programs focusing on the ecological and cultural value of Komodo National Park can transform visitors into active supporters of conservation efforts. These initiatives should communicate how sustainable tourism contributes to long-term preservation goals, echoing IUCN's emphasis on education as a conservation tool.

4.1. Limitations and future requirements

This study employed Importance-Performance Analysis (IPA) to evaluate tourist perceptions and priorities regarding the proposed Jurassic Park development and sustainability attributes within Komodo National Park. While IPA offers accessible and actionable managerial insights—especially in identifying mismatches between what visitor's value and how they perceive current performance—it has several methodological limitations that must be acknowledged. First, IPA is inherently descriptive and does not test causal relationships or explain the underlying psychological or behavioral mechanisms behind tourist preferences. It captures perceptions and importance ratings at a single point in time, but it does not reveal how attitudes are formed, how variables influence one another, or how changes in one domain (e.g., trust in environmental safeguards) might affect support for tourism development. This limitation constrains the model's ability to inform deeper theoretical or behavioral insights.

Second, IPA treats variables independently and does not account for multicollinearity or interdependencies between attributes. For example, preferences for green infrastructure may be strongly linked with beliefs about biodiversity protection or perceptions of risk but IPA does not model these associations. Consequently, it may oversimplify complex relationships between environmental values, socio-demographic factors, and behavioral intentions. To address these limitations, future research could benefit from employing Structural Equation Modeling (SEM), which allows for the testing of direct and indirect effects among latent variables, including attitudes, norms, perceived behavioral control, and willingness to support conservation-linked development. SEM has been widely applied in tourism studies to model visitor satisfaction, destination loyalty, and conservation behavior (Seong et al. 2021; Bhat et al. 2024; Meng et al. 2024; Rahman et al. 2025). Additionally, Network Analysis or Fuzzy Cognitive Mapping (FCM) could be used to understand how tourists mentally connect issues such as climate change, species extinction, infrastructure, and local livelihoods. Network Analysis has been successfully applied to tourism planning and destination governance to map relational complexity and stakeholder influence (Baggio et al. 2010; Wu et al. 2021; Ivars-Baidal et al. 2024). These tools offer a systems-thinking perspective that better reflects the multi-dimensional nature of sustainability in protected areas. Therefore, while IPA is an effective tool for initial stakeholder engagement and practical planning, it should ideally complement explanatory or predictive models in future studies. Combining these methods would allow for a more comprehensive and theoretically robust understanding of visitor behavior and policy preferences particularly in ecologically sensitive and politically complex settings like Komodo National Park.

5. Conclusion

The study conducted on tourist support for the Jurassic Park development in Komodo National Park has provided important insights into the preferences and concerns of both domestic and international visitors. The findings emphasize the need to carefully balance the development of tourism infrastructure with the ecological integrity of a globally recognized conservation area. Visitor support for the project is not unconditional key factors influencing acceptance include environmental awareness, prior visitation experiences, and perceptions of the park's management. Tourists who express concern over environmental risks tend to support the project only if they believe that sustainable practices, environmental safeguards, and clear regulatory controls are in place. The IPA results further revealed mismatches between tourist expectations and the perceived performance of environmental management, waste systems, and green infrastructure indicating priority areas for immediate policy and planning interventions. These findings can be directly implemented by park authorities and private developers to redesign the project scope, prioritize ecological mitigation measures, and improve visitor communication strategies.

However, the success of these implementation efforts depends heavily on political and economic factors. Politically, the central and local government must commit to transparent governance, inter-agency coordination, and the enforcement of environmental regulations, such as AMDAL (environmental impact assessment) compliance. Weak governance or pressure to fast-track development for economic gain could undermine conservation goals. Economically, project implementation must consider the long-term costs of environmental damage versus the short-term benefits of tourism revenue. Investments in sustainable infrastructure such as low-impact transport, eco-friendly lodging, and enhanced waste treatment may require higher upfront costs but are essential for maintaining ecological stability and tourist satisfaction. Furthermore, the involvement of local communities and stakeholders is critical for legitimacy and long-term sustainability. Policy incentives such as revenue-sharing models, job creation in green sectors, and participatory planning can align economic interests with conservation objectives. Ultimately, the study suggests that integrating tourist feedback with strong political will and sustainable economic planning is key to ensuring that the Jurassic Park development enhances rather than threatens the natural and cultural values of Komodo National Park.

CRediT authorship contribution statement

Ari Rahman: Writing – review & editing, Resources, Methodology, Data curation, Funding acquisition, Writing – original draft, Supervision, Visualization, Project administration, Conceptualization, Validation, Formal analysis. **Evi Siti Sofiyah:** Conceptualization, Supervision, Funding acquisition, Methodology, Formal analysis, Writing – review & editing, Data curation. **Imelda Masni Juniaty Sianipar:** Methodology, Funding acquisition, Writing – review & editing, Formal analysis, Conceptualization, Data curation, Project administration, Investigation. **Amalia Edwisafira:** Investigation, Resources, Methodology, Data curation, Formal analysis, Conceptualization, Project administration, Funding acquisition. **Sapta Suhardono:** Investigation, Data curation, Validation, Visualization, Methodology, Formal analysis, Conceptualization, Writing – review & editing, Writing – original draft. **Chun-Hung Lee:** Methodology, Supervision, Resources, Writing – review & editing, Project administration, Data curation, Writing – original draft, Conceptualization. **Van Viet Nguyen:** Writing – original draft, Writing – review & editing. **I Wayan Koko Suryawan:** Writing – original draft, Validation, Resources, Methodology, Project administration, Writing – review & editing, Visualization, Data curation, Supervision, Formal analysis, Conceptualization, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.envc.2025.101229.

Data availability

Data will be made available on request.

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